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XIV.—*Report on the Chemical Examination of Antiquities from the Museum of the Royal Irish Academy.* By J. W. MALLET, A. B., Ph. D.

Presented April 11, 1853.

THE examination of the antiquities to which the present paper refers was undertaken in the hope that more extensive and accurate chemical information, as to the nature of some of the materials employed by the craftsmen who so many centuries ago formed the numerous implements used for purposes of war and peace, which now are to be found in the Museum of the Academy, might be found of value in elucidating the history of the ancient arts by which these implements were produced.

This Museum has afforded peculiar facilities for a research of the present nature, as from the great extent and variety of the objects which it contains, and its general completeness as regards *Irish* antiquities, it was easy to procure a sufficient number of really typical examples in each of the departments examined, without injuring the collection of specimens, as such.

The greater number of the articles submitted to investigation were metallic; the universal applicability of the metals for the purposes of peace and war, of use and ornament, rendering everything calculated to throw light on the materials and processes employed in ancient metallurgy, most important and interesting.

The specimens of this class were most carefully selected, and may, I think, be fairly taken as types of this department of the Museum.

Commencing, then, with the ancient metals and alloys, the first to be described are the

GOLD ORNAMENTS,

of which class of Celtic antiquities I have seen no record of any previous analyses.

Of this metal I analyzed eight specimens, viz.:

No. 1. Fragments of one of the twisted "torques," supposed, I believe, to have been worn round the neck (Museum mark, 513 D). It consisted of a strip of thin plate gold, twisted so as to form a spiral, this being then bent into a circle, and the ends turned into two small hooks, by which the torque was clasped. The ornament had been broken up by the finder into pieces of about two inches long, but when entire its circle must have been ten inches in diameter. The part examined consisted of the two end hooks. The colour of the gold was a pale, rather sickly, yellow, and its specific gravity was 15·377.

No. 2. Fragment of a torque similar to No. 1, and most probably found along with it, in the county of Sligo; but the locality of neither is certain. Museum mark, 516 D. This specimen, which was of a rather deeper yellow colour than the last, was from the middle of the torque. Its specific gravity, 15·444.

No. 3. Part of a twist of wires of about a tenth of an inch in diameter each, the whole length of the twist, which is straight, being about six inches. Locality unknown. This may have formed part of a bracelet, but there is no second specimen in the Academy Museum, and from its workmanship it does not seem likely to be by any means of so ancient a date as the majority of these gold ornaments. The colour was a very deep rich gold yellow, and the specific gravity, 18·593.

No. 4. Two fragments of a lunette-shaped ornament, made of very thin gold plate, and having a little pattern round each edge. The whole must have measured ten or twelve inches across, and the greatest breadth of the flat plate itself was about two inches. It was probably a neck gorget, or ornament for the head, similar to many others preserved in the Museum of the Academy. The locality of the specimen is unknown. It is of about the same colour as standard gold, and of specific gravity, 17·528.

No. 5 was a small plate or spatula of gold, about an inch and a half long, and a quarter of an inch wide. It was probably *unmanufactured* gold, not intended for any special use in its present form. It is not known where it was found. The colour was a little lighter than that of No. 4, and specific gravity, 17·332.

No. 6. Fragment of very thin plate gold, which formed part of a boss or convex ornament, about four inches in diameter, very like those which cover

the ends of the ornaments supposed to be diadems, in the Academy Museum. Locality unknown. It was of nearly the same colour with No. 4, and its specific gravity, 15·306.

No. 7. Specimen of supposed Celtic ring-money. It consisted of a bit of gold wire, of about three-fourths of an inch long, and nearly an eighth of an inch in diameter, bent into a circle, the ends being quite close, but not fastened to each other. It has been stated by Sir WILLIAM BETHAM* that the weights of these rings used for money were graduated with reference to the unit of twelve grains, or half a pennyweight, Troy. This specimen weighed 62·13 grains, or 2 dwt. 12 grs., five of Sir W. BETHAM's units, and 2·13 grs. over. Colour about the same as No. 5. Specific gravity, 17·258.

No. 8. Another specimen of ring-money. It was rather larger than No. 7, but composed of thinner wire. The colour was very much the same with the last, and specific gravity, 16·896. Its weight was 30·04 grains, which is exceedingly close to 1 dwt. 6 grs., or two and a half of Sir W. BETHAM's units. Hence it was about half the weight of No. 7. The localities where these specimens were found are not known.

The results of the analyses† of the gold ornaments were as follow:—

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.	No. 8.
Gold, . . .	71·54	79·48	96·90	88·64	88·72	81·10	86·72	85·62
Silver, . .	23·67	18·01	2·49	11·05	10·02	12·18	12·14	12·79
Copper, . .	4·62	2·48	Trace.	·12	1·11	5·94	1·16	1·47
Lead, . . .	Trace.	· . . .	· . . .	· . . .	· . . .	·28	Trace.	· . . .
Iron, . . .	·	·	·	·	·02	· . . .	Trace.	· . . .
	99·83	99·97	99·39	99·81	99·87	99·50	100·02	99·88

We observe here considerable diversity of composition, and on the whole

* Transactions of the Royal Irish Academy, vol. xvii. Antiquities, p. 7.

† The process of analysis calls for no particular remark, except that the gold was precipitated from the solution made nearly neutral by evaporation, by adding (hot) a slight excess of sulphate of ammonia, which re-agent throws down the metal in the form of a compact sponge, and does not produce the effervescence occasioned by oxalic acid.

the existence of a greater amount of alloy than one would expect from reading the accounts of gold ornaments to be found in various books on antiquities, in which they are often described as of "pure gold," "fine gold," &c., the colour being apparently very often the only guide to such a belief. Although the analyses here given differ much from each other, yet we find some traces of connexion between the composition of the alloys and the forms into which they were manufactured.

Thus, Nos. 1 and 2 are greatly below the standard of the others, and these are both specimens of the same kind of ornament, the torque, and the only specimens examined. They do not differ much from the composition of the electrum of the ancients, as given by Pliny and others.*

No. 6 is about on a par with these as to the quantity of gold, but contains a larger proportion of copper, and less silver.

Nos. 7 and 8 accord very closely with each other, a circumstance particularly interesting from the probability of their having been used as money. For if, as is urged in the memoir on this subject before referred to, these rings really represent a metallic currency of graduated weight, based upon a fixed standard, it surely would be a strong confirmation of this opinion, as well as a fact highly illustrative of the advanced state both of commerce and of metallurgical skill on the part of the fabricators of these rings, if they were shown to be also of constant composition, and that therefore their relative values were actually represented by their proportionate weights. To decide this question, however, more numerous analytical results would be indispensable.

Nos. 4 and 5 in the Table also agree very closely, from which we might surmise that the latter, which probably was not intended for use in the condition in which it was found, was perhaps in process of manufacture into one of the thin lunette-shaped ornaments, like No. 4, which have often been found in Ireland. Its small size, however, renders this more doubtful.

No. 3 is of a much higher standard than any of the others, and approaches fine gold. From its being wire-drawn in the ordinary way through a draw-plate, it is probably not nearly so ancient as the other specimens examined.

* "Ubicunque quinta argenti portio est, electrum vocatur."—*Plinii Hist. Nat.* lib. xxxiii. c. 4.
"Alia (species electri) ex partibus auri tribus et una argenti conflatur."—*Margherit. Philos.* 1523.

In the earliest ages wire appears to have been made by cutting thin plates of metal into strips* and rounding these upon the anvil; and BECKMANN, in his History of Inventions,† seems to think that the modern method dates no earlier than about the middle of the fourteenth century.

If these ornaments presented no appearance of determined composition, and on the whole contained less silver, it might be supposed that they were made of native gold, merely fused, and worked into the required shapes; but from the results actually obtained, although they are by no means conclusive on this point, I think it appears more likely, on the contrary, that these articles were made from alloys artificially produced, and perhaps from determinate quantities of the constituent metals. If this supposition be correct, no information can be derived from these analyses as to the *geographical source* of the surprising quantity of gold found in the manufactured state in Ireland. In Cornwall along with the stream tin, in Scotland, and in much larger quantity in Ireland itself, in the county of Wicklow, native gold has been obtained, and this metal (as well as silver, iron, tin, and lead) is mentioned by Strabo‡ among the products of Britain. It is therefore conceivable that much of the precious metal used in this country may have been found at home, though its quantity would seem to indicate foreign commerce as the more likely channel by which it was procured, unless native gold was anciently much more abundant in Ireland than it has been in more modern times.

SILVER ORNAMENTS.

These are much rarer in Ireland, and throughout the north of Europe, than those of gold, as indeed might be expected in collecting the relics of so distant a period, when we consider that the latter metal occurs, it may be said, invariably in the native state, while the former is found so but rarely, and, in Europe at least, not in any very great quantity; and that the silver ores from which it is most abundantly obtained require the application of much metallurgical skill for the extraction of the metal. Apart, too, from the initial difficulties attendant upon the smelting of its ores, silver, when obtained, is by no means so malleable or easily worked as gold, a circumstance which in some

* Exodus, xxxix. 3. Homer, Odyss. lib. viii. 273-278. † Vol. i. Art. Wiredrawing.

‡ Lib. iv. 30.

degree accounts for the rude workmanship of very many of the Celtic antiquies of this material.

Of the specimens in the Royal Irish Academy collection I selected and analyzed the following eight:—

No. 1. A small ingot of silver, cast in an open mould. Museum mark, $\frac{705}{c}$ 157. It was of a long oval shape, about two inches in length, and half an inch wide. It had two small nicks in one side, close together, as if to mark its weight or value. Its weight was 377·23 grs. = 15 dwts. 12 grs. (+ 5·23 grs.). Hence if used for money it would have been equivalent to 31 or perhaps to 32 of the half-pennyweight units. It was a little tarnished by superficial sulphuret of silver. Its specific gravity = 10·225.

No. 2. A piece of *hexagonal* wire, very neatly made, probably by hammering, about an inch and a half long, and an eighth of an inch in diameter. Museum mark, 809 c. It was bent into the shape of a horse-shoe, and the ends were cut sharply off, so as to induce the belief that it too may have been used for money. It weighed 103·86 grs. = 4 dwts. 6 grs. (+ 1·86 grs.) or about eight and a half units. Its specific gravity = 10·253.

No. 3. End of a taper bangle or penannular bracelet of very rude workmanship. Also, perhaps, occasionally used as money. It was very hard, and rather brittle, breaking with a fine earthy fracture of a yellowish white colour. Specific gravity = 8·770.

No. 4 was a specimen which appeared at first sight to be part of a flat silver bracelet or armlet, stamped with the triangular indentations so common on the silver ornaments of Celtica and Scandinavia, and not broken, but cut across at the ends. Museum mark, $\frac{705}{c}$. On attempting to cut it again, however, it turned out to be a counterfeit, consisting in fact of a core of iron covered with an exceedingly thin plate of silver, which was so skilfully joined as to deceive the eye even on careful observation. This imitation of articles in the precious metals has been observed before in gold rings, which are sometimes found on a thin shell of the valuable material covering a large core of copper or occasionally of lead; but I can find no recorded instance of silver counterfeits of this kind being found among presumed early Celtic antiquities. The iron core of this specimen was much corroded, and the silver was tarnished by sulphuret. Specific gravity of the silver = 10·379.

No. 5. Fragment of a flat armlet, broken across at the ends, and stamped with small square indentations. Museum mark, $\frac{m}{c}$. There were traces of chloride of silver upon the surface, which was much worn. Specific gravity = 10·335.

No. 6. Two fragments of round wire, forming part of a torque large enough for the neck. They are stamped with a small pattern of alternate squares and little pellets in relief. Specific gravity = 10·519.

No. 7. Two fragments of square wire, part of a number of wires twisted into a spiral bundle so as to form an almost solid cylinder. The twist formerly united two silver boxes covered with filigree work. Specific gravity = 10·468.

No. 8. Part of the hinge of a chased hollow bangle, said to resemble common modern Egyptian workmanship; found, it is believed, along with No. 7, and numerous other articles, in a railway cutting near Navan. Museum mark, $\frac{m}{c}$. The silver seems superior in malleability to that of any of the other ornaments examined. Specific gravity = 10·198.

The analysis of these specimens gave the following results:—

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.	No. 8.
Silver, . .	93·93	79·84	37·05	94·69	94·01	92·82	95·87	92·38
Copper, . .	5·44	17·73	60·26	3·11	4·34	5·85	3·59	7·21
Gold, . . .	·42	1·34	1·11	1·80	1·31	·89	·17	·30
Lead, . . .	· . . .	Trace.	·10	· . . .	·06	· . . .	· . . .	· . . .
Tin, ...	· . . .	· . . .	·61	· . . .	· . . .	· . . .	· . . .	· . . .
Iron, . . .	· . . .	· . . .	· . . .	·04	· . . .	· . . .	· . . .	· . . .
Sulphur, .	· . . .	· . . .	· . . .	Trace.	· . . .	· . . .	· . . .	· . . .
	99·79	98·91	99·13	99·64	99·72	99·56	99·63	99·89

The composition of these silver articles does not seem so varied, nor is there the same agreement between the constitution of the particular specimens destined for the same use, as in the case of the gold ornaments. With the exception of Nos. 2 and 3, the whole set contain from 92 to 96 per cent. of silver with 7 to 3 per cent. of copper, and a little gold. The copper might certainly have been derived from the silver ore smelted, and exist in purely accidental quantity; but this seems improbable from the very small quantity of lead detected,

as this metal is a much more frequent mineralogical concomitant of silver than copper is, and from the fact that at least some of the ancients treated their silver ores, just as at the present day, with lead, either in the metallic state, or as sulphuret* (Galena), and subjected the alloy thus obtained to cupellation, which latter process would of course remove the copper. The silver was therefore, in all probability, intentionally alloyed. If *all* these ornaments were, though used as such, occasionally employed also for money, as WORSAAE† and others seem to think, one would be led to suspect that with the silver, as with the gold ring-money, something like a recognised standard metal existed when these articles were in use. This may perhaps be too hasty a conclusion.

Nos. 2 and 3 of these specimens are the only ones which differ remarkably in composition from the others, especially No. 3, which actually contains one-half more copper than silver, though preserving the colour and general appearance of the latter metal. Some, at least, of this large quantity of copper was probably added in the state of bronze, as shown by the presence of a little tin in the silver alloy. On dissolving the silver in nitric acid, the tin remained behind, with the gold forming a "purple of Cassius," of a very good purple colour verging on red.‡ The uniform presence of a little gold in all the silver articles examined is not surprising, since the ancients were, it is almost certain, unacquainted with the process of parting.

I may mention here, in connexion with the silver antiquities, a bluish semi-metallic substance, something like dull or tarnished steel, but very much softer, and brittle, used in the inlaying of small shrines, relic-cases, croziers, &c., of the middle ages. It has not much lustre, but from its colour contrasts very well with either silver or brass, into works in which latter metal it was frequently introduced, but always sparingly. I had very little material to operate on, only about a grain and a half, and consequently was unable to do more

* "Excoqui non potest nisi cum plumbo nigro, aut cum vena plumbi. Galenam vocant, quae juxta argenti venas plerumque reperitur."—*Plinii Hist. Nat.* lib. xxxiii. c. 6.

† *Primeval Antiquities*, pp. 59, 60.

‡ "Purple of Cassius" was obtained in a similar way by M. H. Feneulle (*Ann. de Chim. et de Phys.*, xxxii. 320), on dissolving a number of ancient Roman silver coins in nitric acid. The results of his rather numerous analyses certainly seem to prove that the *Romans* fixed no standard for their silver coinage.

than analyze it qualitatively. It was of a dark bluish-gray colour, approaching black, very brittle, and exhibited a small lamellar fracture when broken.

It consisted, as had been previously known, or at least generally supposed, for the most part of silver; but contained besides, antimony, sulphur, and traces of lead and copper. It may very probably have been made by the partial reduction of some of the antimonial ores of silver, its sole essential constituents being, I believe, silver, antimony, and sulphur.

Having discussed the results of the examination of the antiquities of gold and silver, which principally belong to the class of ornaments, the metallic remains next to be considered are those composed of the important alloy bronze, in primitive ages the universal material for all instruments or utensils in which tenacity and hardness were required, and that are formed of iron in more modern times.

WEAPONS AND IMPLEMENTS OF BRONZE.

These, the forms of many of which are very peculiar, and sometimes very beautiful, and their workmanship frequently such as would not disgrace the artificers of the present day, have early directed the attention of archæologists to the processes used in their formation by the smiths and metallurgists of the epoch to which they belonged. Hence we find several inquiries, more or less extended, on record, aiming at an elucidation of some of these processes by the assistance of chemical analysis. Thus, of specimens found in the British Isles, Mr. ALCHORN,* His Majesty's Assay-master in 1774, examined two bronze swords found in a bog at Cullen, Co. Tipperary, and announced as the result, that the metal was "chiefly copper, interspersed with particles of iron, and perhaps some zinc, but without containing either gold or silver;" adding, "But I confess myself unable to determine anything with certainty."

In 1796, DR. PEARSON† communicated to the Royal Society an account of his analysis of seven specimens of bronze, found in the bed of the river Witham in Lincolnshire, in which he found, copper, 85·7 to 91 per cent; tin, 14 to 9; and in one instance, 0·3 of silver. In 1816, Professor CLARKE,‡ of

* *Archæologia*, vol. iii. p. 355.

† *Philos. Trans.* 1796.

‡ *Archæologia*, vol. xviii. p. 343.

Cambridge, analyzed portions of bronze vessels found near Sawstone, Cambridgeshire, and found them to consist of 88 per cent. of copper, and 12 per cent. of tin. This same composition has recently been found for Irish specimens by Dr. ROBINSON of Armagh.* Professor E. DAVY,† Mr. O'SULLIVAN,* Mr. DONOVAN,* and Mr. J. A. PHILLIPS,‡ have published more complete analyses of antiquities from the latter country, in which foreign metals (as lead, silver, and iron) have been carefully sought for, and their quantity determined; and a similar accurate examination of Scottish relics of bronze has been made by Mr. WILSON, Hon. Sec. of the Society of Antiquaries of Scotland.§ Of these investigations that of MR. PHILLIPS is the most important as regards Ireland.

The specimens from the Museum of the Academy which I have examined were all found in Ireland; and are, as a group, completely illustrative of the principal classes of antiquities belonging to that country. They are sixteen in number.

No. 1. A flat celt or kind of hatchet, the most common weapon of bronze found in Ireland, Museum mark, $\frac{439}{B}$. This specimen was discovered, it is believed, in the county of Cavan; it is a fine hard bronze, of a deep brass-yellow colour, the "Celtic brass" of antiquaries. It was in excellent preservation, being scarcely even tarnished on the surface. Specific gravity, 8.631.

No. 2. Another flat celt, with rounded edges; locality unknown. Museum mark $\frac{438}{B}$ 395. It was slightly and uniformly corroded on the exterior, and on being filed proved to be a much softer bronze than No. 1; of a copper-red colour, a little lighter than that of pure copper. Specific gravity, 8.303.

No. 3. A long hollow celt, resembling in shape specimens which have been found in Denmark, discovered in the county of Wicklow. Marked, M'Enty. It was a hard and rather brittle bronze, of about the same colour as No. 1; slightly and uniformly corroded. Specific gravity, 7.960.

No. 4. A short hollow celt, of very good workmanship, and exhibiting scarcely a trace of corrosion; supposed to be from the county of Cavan. Museum mark,

* Proceedings of the Royal Irish Academy, vol. iv. pp. 430-469.

† Wilson's Archæology of Scotland, p. 247.

‡ Quarterly Journal of the Chemical Society, October, 1851.

§ Wilson's Archæology of Scotland, p. 245.

Farnham, 38. The metal was very soft, and resembled No. 2 in colour, but was not quite so red. Specific gravity, 8·428.

No. 5. A long spear-head, ribbed upon each side ; of excellent workmanship, and not at all corroded. Mark, $\frac{2}{5}$. The bronze was hard and uniform, and had received and retained a very good edge ; colour about the same as No. 1. Specific gravity, 8·581.

No. 6. Portion of a spear-head, marked $\frac{11}{5}$; a flat, thin blade, with a beautiful edge ; the surface perfectly smooth and polished, but tarnished of a deep brown colour, resembling, I believe, the appearance of the bronzes called “Cinque cento.” This skin of brown upon the outside was eaten through in some places by superficial corrosion. When filed, the metal was found to be exceedingly hard, and of a yellow colour, something deeper than No. 5. Specific gravity, 7·728.

No. 7. A flat scythe, found in the county of Roscommon. Museum mark, $\frac{11}{4}$. Several similar articles were found with this ; they were slightly curved blades, of about twelve or fourteen inches long, and tapered in breadth from about three inches at one end to a rounded point at the other. They had been attached to a handle at the broad end by three rivets. The specimen examined was a copper-coloured bronze of no great hardness, and but slightly corroded on the surface. Specific gravity, 8·404.

No. 8. Portion of a sword-handle ; locality unknown. Museum mark, $\frac{101}{A}$ [101]. It was part of the characteristic Celtic weapon, in which the hilt of the handle and blade were cast in a single piece, the former part being generally remarkable for its shortness as compared with those of modern times. This specimen was made of a beautiful compact metal, very hard, and of a yellow colour, like that of No. 1, but a little deeper. No corrosion upon the surface. Specific gravity, 8·819.

No. 9. Part of the blade of a sword of the same character as the last, but made from a metal by no means so hard or good. Mark, $\frac{100}{A}$ [100]. It was similar in colour internally to No. 8, but was much more corroded on the outside. Specific gravity, 8·487.

No. 10. Portion of a dagger or Irish knife (found near Newry ?) Marked $\frac{1}{5}$. A good hard bronze, very like No. 8 in colour and external appearance, and rather more malleable. It was scarcely tarnished. Specific gravity, 8·675.

No. 11. Fragment of a chisel, marked $\frac{100}{8}$, made of very inferior bronze, copper-coloured, soft, and not uniform in texture. It contained cavities produced by air-bubbles in the casting, and was very much corroded; oxide of tin, carbonate of copper, and the *red dinoxide of copper* were observable on the surface. Specific gravity, 7·896.

No. 12. Specimen of the bronze ring-money which is found in such great quantity in Ireland. It was a small ring (about an inch in diameter), in form a simple circle, cast in a single piece, and having no opening like those in the specimens of gold and silver, by which the rings might be strung together into a chain. Its weight was 100·53 grs. = 4 dwts. 4·53 grs., or about eight of the units spoken of before. The bronze was moderately hard, of a deep brass-yellow colour, very little corroded, but having a slight film of green “æругo” on the surface. Specific gravity, 8·072.

No. 13. Specimen of ring-money of a larger size than the last, being about two inches in diameter: locality unknown. It differed from it also in being *hollow*, cast upon a core of fine siliceous sand, which had not been extracted, but remained firmly imbedded in the bronze. There were two small projections on opposite edges of the ring outside, and the metal and core were pierced at these bosses by a hole apparently intended to allow a string to pass, by which the rings might be strung together. If used as money, this method of attaching the separate pieces would be certainly less convenient than merely stringing the rings themselves through the centre. Might not these articles have been made as parts of necklaces, or other ornaments for the person, though perhaps also used occasionally as a circulating medium? The weight of the specimen, *including the sand core*, = 388·43 grs. = 16 dwts. 4·43 grs. = about 32 of the half-pennyweight units. The bronze was very like that of No. 12, but much more brittle. Its surface had been smooth and polished, but was slightly pitted in some places by corrosion. Specific gravity, 8·231.

No. 14. Fragment of a large cauldron or tall vessel of thin sheet bronze. From its size (about 2 ft. 6 in. high), and the thinness of the plates of which it was made, it displays a degree of skill and neatness in the treatment of bronze most remarkable as existing at so early a period as this vessel probably belongs to. The metal is not very hard, but extremely tough, and is of a beautiful rich bronze-yellow colour (“gold bronze”), scarcely altered by time. Specific gravity, 8·145.

No. 15. Portion of a small oval-shaped bell, made of a deep yellow bronze or bell-metal, hard and brittle. The surface was rough, but not much corroded. Specific gravity, 8·094.

No. 16. Fragment of a small square bell; the metal about as hard as No. 15, nearly of the same colour also, but not so brittle. It was more corroded, and did not seem so good a material for the purpose. Specific gravity, 7·708.

These specimens, being carefully analyzed, gave the results contained in the following Tables.

(In each case a minute qualitative analysis was first made, and the absence of other metals than those afterwards estimated in quantity ascertained).

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.	No. 8.
Copper, ...	86·98	98·74	88·30	95·64	86·28	84·64	95·85	87·07
Tin, ...	12·57	1·09	10·92	4·56	12·74	14·01	2·78	8·52
Lead, ...	· . . .	· . . .	·10	·25	·07	· . . .	·12	3·37
Zinc, ...	· . . .	· . . .	· . . .	· . . .	· . . .	· . . .	· . . .	· . . .
Iron, ...	· . . .	·08	Trace.	· . . .	·31	Trace.	1·32	· . . .
Cobalt, ...	· . . .	· . . .	· . . .	· . . .	·09	· . . .	· . . .	· . . .
Gold, ...	Trace.	Trace.	· . . .	· . . .	· . . .	· . . .	· . . .	· . . .
Silver, ...	·37	·06	· . . .	·02	· . . .	· . . .	· . . .	· . . .
Arsenic, ...	· . . .	· . . .	Trace.	· . . .	· . . .	· . . .	· . . .	· . . .
Antimony, ...	· . . .	· . . .	· . . .	· . . .	· . . .	· . . .	· . . .	· . . .
Sulphur, ...	· . . .	· . . .	· . . .	· . . .	· . . .	·03	· . . .	Trace.
	99·92	99·97	99·32	100·47	99·49	98·68	100·07	98·96

	No. 9.	No. 10.	No. 11.	No. 12.	No. 13.	No. 14.	No. 15.	No. 16.
Copper, ...	87·94	90·72	91·03	87·24	85·89	88·71	84·78	85·92
Tin, ...	11·35	8·25	8·39	9·58	13·83	9·46	12·90	11·73
Lead, ...	·28	·87	· . . .	2·79	Trace.	1·66	2·04	1·72
Zinc, ...	Trace.	· . . .	· . . .	Trace.	· . . .	· . . .	·06	· . . .
Iron, ...	· . . .	· . . .	· . . .	· . . .	· . . .	·03	· . . .	Trace.
Cobalt, ...	· . . .	· . . .	Trace.	· . . .	· . . .	· . . .	· . . .	· . . .
Gold, ...	· . . .	· . . .	· . . .	· . . .	· . . .	· . . .	· . . .	· . . .
Silver, ...	· . . .	· . . .	· . . .	Trace.	· . . .	· . . .	Trace.	· . . .
Arsenic, ...	· . . .	· . . .	· . . .	· . . .	· . . .	· . . .	·03	Trace.
Antimony, ...	· . . .	· . . .	·04	· . . .	· . . .	· . . .	· . . .	· . . .
Sulphur, ...	Trace.	· . . .	· . . .	· . . .	Trace.	· . . .	· . . .	· . . .
	99·57	99·84	99·46	99·61	99·72	99·86	99·81	99·37

The composition of these specimens agrees *in general* with that of the articles which have been examined by the authors referred to before, and also accords pretty closely with the quantities synthetically employed by the ancient metallurgists of whose labours we have any account. Thus, Pliny tells us* of the method adopted in his day for making bronze, which, however, he obviously treats of principally as a material for statues and public monuments. "Massa proflatur in primis, mox in proflatum additur tertia portio æris collectanei, hoc est, ex usu coempti. Peculiare in eo condimentum atritu domiti, et consuetudine nitoris veluti mansuefacti. Miscentur et plumbi argentarii pondo duodena ac selibræ, centenis proflati. Appellatur etiamnum et formalis temperatura æris tenerrimi, quoniam nigri plumbi decima portio additur et argentarii vigesima: maximèque ita colorem bibit, quem Græcanicum vocant. Novissima est quæ vocatur ollaria, vase nomen hoc dante, ternis aut quaternis libris plumbi argentarii in centenas æris additis. Cyprio si addatur plumbum, color purpuræ fit in statu arum prætextis." The analyses also of antiquities, not of Celtic origin, as those by KLAPROTH,† DIZE,‡ MONGEZ,§ GÖBEL,|| and pupils of ERDMANN,** all approach each other within rather narrow limits, and differ little from those at present under consideration.

The cause of this general accordance is obvious, namely, that the physical properties required in these alloys of copper and tin are only to be found within a small range of variation in chemical composition. Dr. ROBINSON†† has given it as his opinion, that, when used for weapons, the atomic constitution of Celtic bronze was constantly $14 \text{ Cu} + \text{Sn}$; but though this formula may and probably does represent the best alloy for the manufacture of implements for warlike purposes, or others in which similar requirements exist, yet it cannot be said that it invariably accords with the actual composition of the antiquities in question, as No. 6 of the analyses in the Table is near $11 \text{ Cu} + \text{Sn}$, while No. 4 approaches $39 \text{ Cu} + \text{Sn}$, and Nos. 2 and 7 contain still more copper, though perhaps the former of these should hardly be considered as bronze.

As on the one hand we must not conclude that a simple and invariable

* Hist. Nat. lib. xxxiv. c. 9.

† Gehlen's Journal, No. 15, and Journal des Mines, Mars, 1808, p. 161.

‡ Journ de Phys, 1790.

§ Mém. de l'Institut.

|| Schweig. Journ. 60, 407.

** Journ. für pr. Chem. xl. 374.

†† Proc. Royal Irish Acad., vol. iv.

proportion existed in the quantities of the component metals of these bronzes, so, on the other, it seems erroneous to infer, as MR. WILSON, in his *Archæology of Scotland** has done, that the absence of such invariable composition necessarily proves that these antiquities were the work of native artists, who were unable to combine the metals they used with the accuracy and certainty of foreign metallurgists of the same epoch. For, passing over all the difficulties which the primitive modes of reduction of the respective ores, and the impurities consequently retained by the metals, must have presented to the early manufacturers of any nation, and supposing the copper and tin used to be each perfectly pure, the task of producing from these materials an alloy of definite and uniform composition is, even at the present day, one requiring great skill, both in the actual process of melting, and in the previous construction of furnaces, &c., so that for the purpose and at the period of the manufacture of the articles in question it must almost be deemed impossible of accomplishment.†

Hence the observed variations of composition between the several bronze antiquities found in Ireland by no means negative the possibility, to say the least, of their having been produced by a single people, and that one, far advanced in the art of metallurgy for the age to which these articles are referred.

Yet, although these differences of composition are probably to a very great extent owing to the want of sufficient skill and appliances to produce from the same materials uniform results,—difficulties enhanced to the last degree where many *small* articles are to be cast, at separate operations, and from alloys formed in small quantities,—and are therefore to be looked upon as unintentional,—yet some marks of design may perhaps be traced in the differences between the alloys of articles intended for different purposes. Thus we find two of the celts (Nos. 2 and 4) and the war scythe (No. 7) consist almost entirely of copper, the quantity of tin amounting in No. 2 to only 1·09 per cent., a proportion so small that it might be supposed to be derived merely from the addition of fragments of old bronze to the copper, or from imperfect reduction of the ore.

* Page 249.

† The principal difficulty arises from the “burning out” of the tin, which takes place with great rapidity on access of air to the melted bronze. The column in the Place Vendôme, Paris, was a remarkable instance of mismanagement in this respect, almost the whole of the tin having disappeared from the metal employed to cast some of the blocks of bronze.

The only analysis of Celtic bronze containing so much copper, that I have seen, is that of a broken spear-head found in Ireland, examined by Mr. PHILLIPS,* from which he obtained 99·71 per cent. of copper, and ·28 of sulphur. The composition of the metal used in casting the celebrated Quadriga of Chios (better known in this country as the Horses of St. Mark's, Venice), as determined by KLAPROTH,† was also very near that of the present specimens, being 99·13 per cent. copper, and ·87 tin. Some ancient nails analyzed by the same chemist,‡ and Greek and Roman coins examined by Mr. PHILLIPS,§ and pupils of ERDMANN,|| also appear to have been made from nearly pure copper.**

The other celts (Nos. 1 and 3), one of the spear-heads (No. 5), and one of the swords (No. 9), agree pretty closely in composition; containing about 87 or 88 per cent. copper, and 13 or 12 of tin, if we disregard all traces of foreign metals. This is the composition assigned by Dr. ROBINSON as the best for the purpose, and his opinion seems in fact borne out by the results before us, as the specimens numbered 1, 3, and 5, were certainly very far superior to most of the others in hardness, toughness, and uniformity; and the alloy having this constitution may be considered as the normal one, *at least where other metals than copper and tin are present only in insignificant quantity*; for 2 or 3 per cent. of a foreign metal, as lead, seems to exercise a very great influence in changing the character of the whole. Thus the sword (No. 8) in which the tin amounted to only 8·52 per cent., but which contained besides 3·37 per cent. of lead, fully equalled the weapons just mentioned in hardness, and perhaps even exceeded them in malleability and facility in working.

The second of the two spear-heads (No. 6) was exceedingly hard, and had received a good edge, but it had not the same toughness as the others, and had broken across without bending; hence so large a proportion of tin as it contains, 14·01 per cent., does not seem to yield a metal so well adapted for weapons.

The two daggers or knives (Nos. 10 and 11) agree very closely in composition, yet the difference in physical properties is most marked.

* Quart. Journ. Chem. Soc., *loc. cit.*

† Beiträge, vi. 89. Gehlen's Journal, No. 15.

‡ Gehlen's Journal, *loc. cit.*

§ *Loc. cit.*

|| Journ. pr. Chem. xl. 374.

** The presence of sulphur is highly interesting as giving the strongest presumption that the copper of these ancient alloys was obtained from the imperfect reduction of sulphuretted ores of that metal.

No. 10 was a bronze of excellent quality, a little softer than No. 8, but still sufficiently hard, tough, and uniform, and not at all corroded; while No. 11 was soft, full of cavities, not uniform in texture, and was covered with the results of corrosion. (Of course in this, as in every other instance in which the corrosion of metals is examined, regard ought to be had to the situation in which they have been discovered; but unfortunately, in the present case, information on this head is entirely wanting.) Additional analyses of very inferior bronzes and those which have suffered most from corrosion, taking care to examine fragments taken from different parts of the same article, might yield results of interest, and possibly of practical importance.

The cauldron or vase of thin sheet bronze (No. 14) contained about the same per-centage of copper as the bright yellow-coloured alloy for weapons (rather more than 88 per cent.), but not quite so much tin, its place being partly supplied by about 2 per cent of lead, which tends to make the alloy more malleable.*

The two specimens of ring-money (Nos. 12 and 13) contain quantities of copper differing by nearly 1·5 per cent., while the proportion of tin varies still more, being 9·58 per cent. in the former, and 13·83 in the latter. In the one we find 2·79 per cent. of lead, but in the other a mere trace of that metal is perceptible. Hence, it is obvious that, as far as these specimens are to be considered as representing the ancient Celtic currency of bronze, no very accurate standard of alloy was observed in its production. This is not surprising; the formation of such a definite and constant alloy being, as above mentioned, attended with so much difficulty, and the inferior value of the material rendering it by no means as important as in the case of gold or silver. The rings being merely cast, and not struck like ordinary coins, the physical properties of the metal did not need so much attention as in the case of arms or implements, where they were of the first importance.

The samples of bell-metal examined, numbered 15 and 16, differ but little from each other. The quantity of copper is considerably greater than that generally employed at the present day. This may have been owing to the desire of the early artists to avoid brittleness in the metal, but more probably to the

* Modern workmen are well aware that the addition of about 2 per cent. of lead greatly improves the working qualities of brass and bronze, causing both to cut smooth and sharp in the lathe, or, as French brass-workers express it, to cut "*seché*."

"burning out" of the tin by some rude and slow process of melting. The composition of these specimens is very simple, copper and tin being, as in all the other ancient bronzes, almost the sole constituents. Modern bell-metal is occasionally much more complex, containing, according to THOMPSON,* 80 per cent. of copper, 5.6 of zinc, 10.1 of tin, and 4.3 of lead.† Those Irish bells are, it is needless to say, of much more recent date than the bronze weapons, and belong, it is believed, to about the eighth or ninth century.

With respect to the foreign metals found in minute quantities in these alloys, although, with the exception perhaps of lead, they may all be fairly considered as accidental, and merely introduced as impurities of the constituent metals, yet they are not to be neglected, as in the consideration of antiquities they may occasionally yield some valuable collateral information. The lead which is found in many of the specimens, and has been previously detected in much larger quantity in some bronzes, might have existed as an impurity of the copper, but was more probably added either intentionally in the separate state, or existing in older bronze remelted, which often contained this metal, particularly when used for statues. Zinc was only observable in minute traces in three of the bronzes, but its presence in these *was distinctly ascertained*. In all probability it was introduced along with the copper, and was derived from blende occurring along with the ore of that metal, and imperfectly separated from it. Though found in large quantity in some early Roman coins, and by GÖBEL‡ in wire from a Livonian tomb, I believe it has not before been detected in Celtic bronze. Iron might have come in with either of the constituent metals, and has been observed in previous analyses. Indeed, from its universal diffusion in nature, its absence in these alloys would be more surprising than its presence. Our finding the rarer metal, cobalt, though only in two instances, is more remarkable; these, however, are not the only antique bronzes in which it has been observed, as Mr. PHILLIPS, in his valuable paper

* Ann. Phil. 2. 209.

† M. GIRARDIN found the composition of the "cloche d'argent," an ancient bell at Rouen (previously thought to have contained a large proportion of silver, from oblations made at the time of its founding), to be, copper, 71; tin, 26; zinc, 1.80; and iron, 1.20 = 100. (Ann. de Chim. et de Phys. 50. 205.) The proportion of copper here is very small.

‡ Schweig. Journal, 60. 407.

alluded to above, notices it and nickel as occurring in several early coins, and in one Irish specimen, a celt, to the amount of 0.34 per cent. (with a trace of nickel). The minute quantities of the Precious Metals were perhaps derived from fragments adhering to old ornaments of bronze, which were afterwards re-melted. It has been supposed that traces of silver found in one or two previous analyses were owing to the lead not having been freed from this metal, and this was probably often the case, but in two instances here (Nos. 1 and 2) it could not have been so, as no lead was present. Arsenic and antimony have not, I believe, except in one instance, been hitherto noticed in similar alloys,* and existing in such very small quantity, are not easily detected; but by employing a separate portion of bronze for the purpose, I determined rigidly the question of their presence or absence. The source of these traces found in the alloy is not difficult of explanation. Indications of sulphur (and of carbon, by Mr. DONOVAN) have been observed in several specimens previously analyzed; these, and the traces of arsenic and antimony, are interesting, as rendering it at least probable that some of the copper used by the ancients was smelted from sulphuret of copper or copper pyrites (probably the chalcitis or misy of Pliny), or other ores of the same class, and that native copper, red oxide of copper, and malachite, did not, as some authors seem to suppose, constitute their only sources of the metal.

The question, from what countries were the copper and tin, employed to such an immense extent by the nations of antiquity, derived, is one of great interest, and has been already treated of, especially with reference to the source of the tin, by several authors of celebrity. They seem generally agreed that the former of these metals was discovered, and extracted at a very early period in several places in the south and east of Europe, and adjoining portion of Asia. At the period of the Trojan War, and at the time of the building of Solomon's Temple, the supply of copper must have been most abundant, and the name frequently occurs in the Pentateuch. The art of casting statues of bronze is ascribed by Pausanias to Rhæcus and Theodorus of Samos (about 700 or 800 B. C.), at which time it must of course have become common, though we have

* Jahn (Ann. Pharm. 27:338) found 8.22 per cent. of antimony in an ancient weapon from the ruined castle of Henneberg.

but little knowledge of the localities from which it was derived. When Pliny wrote, its principal sources were Cyprus, Campania, Gaul, and Spain, especially the last-named country. Although England now supplies a very large proportion of all the copper made use of in the world, there are no traces in history of any having been smelted here so early as the Celtic period, and the contrary seems to be proved by a passage of Cæsar, *De Bell. Gall.*,* where he says of Britain: “Nascitur ibi plumbum album in Mediterraneis regionibus, in maritimis ferrum, sed ejus exigua est copia, *ære utuntur importato*.” Strabo† also enumerates gold, silver, iron, tin, and lead, among the products of Britain, but does not mention copper, the sixth of the then well-known metals, which it is improbable he would have omitted if its being found there were familiarly known.

It seems on the whole most probable that by far the largest portion of the tin used in the manufacture of the bronze of antiquity was brought from Cornwall by Phœnician or other merchants, and by them distributed over the south of Europe, Syria, and Asia Minor. Strabo‡ and Pliny§ indeed state that it came from Spain, and tinstone is known to exist in that country in the province of Gallicia, but the quantity there found is not likely to have supplied the whole demand for this metal; and their account is easily explained by the consideration that the great commercial depot of the eastern merchants was probably situated somewhere near Gades (now Cadiz) in the south of Spain, and that to this place the tin was brought from the west, and from it was again distributed to the consumers in the Mediterranean. Aristotle distinctly mentions, “τὸν κασσιτερον τὸν Κελτικόν” in his treatise, *De Mirab. Auscult.*

Though Pliny|| tells us of tin, “Nulli rei sine mixturâ utile,” yet it was obviously well known in the separate state, as in Homer we read of the breastplate of Agamemnon:

“Τοῦ δ’ ἦτοι δέκα οἶμοι ἔσαν μέλανος κῦάνοιο,
Δώδεκα δὲ χρυσοῖο, καὶ εἴκοσι κασσιτέροιο.”

—*Il.* xi. 24.

And the same poet mentions metallic tin in several other places. Hesiod does

* *Lib.* iv. c. 34.

† *Lib.* iv. 305.

‡ *Lib.* iii. p. 219. ed. Almel.

§ *Lib.* xxxiv. c. 16.

|| *Loc. cit.*

so too, and Aristotle and Pliny speak of it as a known and common substance. Yet antiquities of this metal unalloyed are very rare ; indeed there have been, I believe, but three instances recorded in which such have been found in Great Britain,—and these all in England.* Hence a single additional specimen found in the collection of the Academy acquires considerable interest. It filled the interior of a hollow bronze ring of about four inches and a half in external diameter, the thickness of the ring being about half an inch. It was easily recognised as tin by its colour and the resistance it offered to the knife, and on chemical examination it proved to be nearly pure, containing mere traces of iron and lead. Where partially exposed to the atmosphere it had acquired a coating of peroxide. From the way in which it is attached to the bronze, and the character of the latter, it would seem with little doubt to belong to the same period as the other early bronze antiquities in the Museum.

In the collection there is an earthen vessel, apparently intended to be placed in the fire, in which were found several small fragments of bronze very much corroded, a brown earthy powder in which particles of the “æru^go” of bronze were observable, and a bit of a white metal of considerable lustre, and exhibiting a somewhat lamellar structure. This latter was hard and very brittle, so as to be easily reduced to powder in a mortar. There were no traces of corrosion on the surface. Specific gravity, 8·107. On analysis it gave in 100 parts,

Copper, ...	66·12
Tin, ...	30·62
Silver, ...	·13
Antimony, ...	1·91
Sulphur, ...	·11
	98·89

Thus, though an alloy of copper and tin, it differs totally from bronze in the proportion of its ingredients. The only analysis I have seen which comes near this is that of an antique Roman mirror by KLAPROTH,† in which he found, copper, 62; tin, 32; and lead, 6; = 100. Whether the Irish alloy was intentionally

* Phil. Trans. vol. xxiii. p. 1129, and vol. li. p. 13. Archæologia, vol. xvi. p. 137.

† Scherer's Allgem. Journ. d. Chemie, No. 33.

made to be used for a similar purpose,—a supposition in some degree countenanced by the presence of a little antimony,—or that the proportion of tin was accidentally large, and the specimen was about to be remelted, and perhaps copper added, is not easy to decide. The pulverulent substance found in the same vessel was neither an ore of any kind, nor a furnace product, but appeared on examination to have been merely dust of an earthy character mixed with the results of bronze corrosion (probably the sweepings of a workshop or some such place). The vessel and its contents constitute an interesting relic of early metallurgy.

Although *Zinc* in the metallic state was unknown, at least until the twelfth century, it seems certain that some of its ores were worked and used for making Aurichalcum or brass at an extremely early period, the valuable properties of that alloy being well known and appreciated in Aristotle's time, although he speaks of it under the title χαλκὸς Μοσσύνουκος as a rare variety of bronze. This Pliny also considered it, and it seems never to have come into common use amongst either the Greeks or Romans. Hence it is not surprising that no example of a brazen article of decidedly Celtic manufacture has yet been discovered. I analyzed a fragment of a shallow basin from the district of Castlebernard, County of Cork, recently presented to the Academy Museum, and found it to contain :—

Copper, ...	72·58
Zinc, ...	25·29
Iron, ...	1·16
Lead, ...	·02
Tin, ...	Trace.
	99·05

The specimen was soft, of a bright brass-yellow colour, and specific gravity, 7·717. From its form, however, and composition, which is quite that of ordinary modern brass, it is probably of very little antiquity, and does not at all belong to the same class with the really Celtic articles in the Museum; an alloy therefore of copper and zinc of equal age with the latter is still to be sought for. Amongst German antiquities GÖBEL (Schweig. 60. 407.) found

some of this composition, but I do not know to what date or people his specimens have been assigned by archæologists.

Lead is another of the metals which was extracted from its ores and applied to many of the purposes for which it is used at the present day, at probably a period nearly as ancient as that of the introduction of copper. With the exception of native metals, no ore would be more likely to have come under the notice and attracted the attention of primitive metallurgists than galena, the commonest form in which lead occurs, and from which its extraction would present scarcely any difficulty even with the rudest means for smelting. Mention is accordingly made of this metal among the Egyptians, Hebrews, Greeks, Romans, and other nations of antiquity, who not only used it in its separate state for water-pipes and other mechanical purposes, but were also acquainted with the method of employing it in the refinement of gold* and silver.† In Britain, particularly in Derbyshire, numerous remains of lead-workings have been discovered, probably belonging to the time of the Roman occupation, but I have seen no account of any relics of this metal of similar antiquity having been found in Ireland; and in the Museum of the Academy, the only traces of lead that I could find were the cores or filling of one or two reliquaries of thin gold plate or foil, which are, I believe, considered as specimens of mediæval art. The interior surface of one of these cores, which was itself hollow, was considerably corroded, being covered with a grayish crust of carbonate, the production of which was probably accelerated by the contact of the gold. Some ancient lead from an abbot's coffin in the Cathedral of Christ Church, Dublin, which was deeply pitted by corrosion, yielded traces of sulphate along with the carbonate upon its surface, and on cupellation of the metal itself left a minute bead of silver.

Of the numerous

WEAPONS AND IMPLEMENTS OF IRON

I examined four, namely:—

No. 1. A sword found at Kilmainham, near Dublin. It is long and straight, adapted for both cutting and thrusting, and is one of those examined by M. WORSAAE on visiting the Museum a few years ago, and declared by him to

* Theognis—Γρυμαι. l. 1101.

† Jeremiah, vi. 28. Pliny. lib. xxxiii. c. 6.

agree in appearance with Norse swords preserved at Copenhagen and Stockholm. The blade was covered with a thick coat of rust, on removing which a portion of metal beneath was reforged as the simplest way of determining its character. It turned out not to be steel, but moderately good soft iron, incapable of being hardened by quenching when hot in water. On solution in dilute sulphuric acid it left a very slight black sediment, consisting of carbon with traces of phosphorus.

No. 2. A Knife, also found at Kilmainham, marked $\frac{22}{5}$; still more corroded than the last, there being in fact very little metal left. The fracture was very close-grained, and of a bluish-white colour; and on reforging it proved to be steel of an inferior quality, leaving, on solution in a dilute acid, carbon, containing phosphorus and silica, the quantity of which was, however, not determinable. The specimen is probably a very modern one, and ought not to be classed with the others here described.

No. 3. A nail from Dunshaughlin in the county of Meath. It was not nearly so much corroded as the last two specimens, and the rust was hard and closely adherent, whereas that on the sword and knife was loose and easily detached. On the crust of oxide some traces of the blue phosphate of iron were observable, and more was to be found on breaking it off from the metal. The latter, on reforging, proved, as might have been expected, to be soft iron, containing, as was found on chemical examination, a large proportion of phosphorus as compared with the other specimens.

No. 4 was another knife, of a small size, narrow-bladed, and thick on the back, discovered at Strokestown in the county of Roscommon. It was covered by very little rust as I got it, but had apparently had some corrosion previously removed. It consisted, not of steel, which it somewhat resembled in appearance, but merely of malleable iron, of excellent quality, which dissolved almost perfectly in dilute sulphuric acid, leaving a barely visible trace of carbon, and affording no indications of phosphorus.

From these experiments we see, so far as their limited number renders it allowable to judge, that the really ancient weapons of this class found in Ireland do not consist of steel, but of soft iron. This would be in itself an interesting fact if confirmed by further investigation, as showing that the early Scandinavians and Celts, or those who supplied them, though able to make good mal-

leable iron in the first instance, but were ignorant of the methods of giving it the properties of steel by any after-process, though it is plain from passages of Greek and Roman authors* that the latter substance was known to them. The subject, however, demands further investigation.

Having concluded the account of the metallic antiquities, I proceed now to the examination of some other objects, principally used for ornament. And first of—

PRECIOUS STONES.

Of these I found seven varieties, at least according to the classification of the jeweller, though not all distinct mineralogical species, viz. sapphire, beryl, turquoise, garnet, amethyst, clear rock-crystal, and chalcedony. The determination of the periods when these were used as ornaments is of course altogether an antiquarian question, and I do not know to what dates these individual specimens are referred; but with the exception, perhaps, of some of the articles of crystal, none of them seem to belong to the period of the Celtic makers and users of the gold and bronze objects above examined. Some of the amethysts found in crosses and other ecclesiastical relics are merely the uncut terminations of quartz crystals of the common form, no part of the prism, but only the hexagonal pyramid, being visible. Some of the sapphires, which are small and uncut, have been most probably found in the county of Wicklow, with rolled pebbles of the mineral occurring in which county they agree perfectly in external characters.†

Four beads of *amber* which I examined, of different degrees of transparency and colour, were quite unchanged in chemical properties, and, except one, presented nothing remarkable in appearance; this, on being split, was found to be white and nearly opaque (wax amber) in the interior, while the exterior, including the surface of the hole, piercing the bead, was orange-yellow and transparent, like the more ordinary variety of this substance, to a depth of about the twentieth of an inch. This change of molecular condition must, I imagine, have

* See Aristotle, *De Mirab.* Pliny, lib. xxxiv. c. 14. Dr. PEARSON (*Phil. Trans.* 1796) found all the supposed iron weapons, from Lincolnshire, which he examined, to consist of steel.

† See the author's *Examination of Gold Sand of Wicklow.* *Proceedings of Geological Society of Dublin* for 1851–52.

been the result of age ; unless indeed the bead had at some time been immersed in oil or any similar fluid, which had penetrated it to the extent described.

Two or three fragments of *jet* examined proved, as might be expected, unaltered specimens of this variety of coal.

COLOURED GLASS BEADS.

These occur of several distinct colours ; the most common are, two shades of blue, a black (in reality intensely deep green), a very pale sea green, and white ; of each of which I received a specimen for qualitative analysis.

No. 1 was a very fine dark-blue bead, from Kilmainham, quite resembling good modern cobalt glass in colour, but full of minute air bubbles. By fluxing with an alkali, solution in muriatic acid, and the application of the usual re-agents, the colouring matter was found to be oxide of cobalt, but the glass also contained a trace of copper. Whether the latter was accidental, or, being known to tinge glass blue or green, was added with the intention of improving the colour, it would be impossible to say. It was contended by GMELIN* that the blue glass of the ancients was not stained by cobalt but iron (that it was analogous to ultramarine) ; and an ancient specimen of a sapphire blue colour, analyzed by KLAPROTH,† gave no indications of the former metal ; but Sir H. DAVY‡ found cobalt in all the glass vessels of this colour from the tombs of Magna Græcia, and the same colouring material has been detected in the beads found upon Egyptian mummies. The present is therefore but an additional instance of the use of a compound of this metal for a special purpose being known long before the metal itself or any of its preparations had been obtained in a state approaching purity.

No. 2. A bead of so dark a bottle-green colour as to appear by reflected light quite black and opaque. In very thin splinters it was translucent, and of the above tinge. The colouring material was oxide of iron, in very large quantity, and traces of manganese were also distinctly perceptible. The specimen was from Templepatrick in the county of Antrim, nearly spherical, well shaped, and had a finely polished surface.

No. 3 was a blebby, light blue bead, verging on green, from Kilmainham.

* Götting. gel. anz. 1776.

† Beiträge. s. 144.

‡ Phil. Trans. 1815, p. 108.

But for the contained air bubbles it would have been nearly transparent. The colour was due to oxide of copper ; and both in the staining of the glass, and in forming the bead, the specimen was a very rude result of early art.

No. 4 was a flattened bead, also from Kilmainham. It was more nearly transparent than any of the others, and had only a very faint tinge of sea-green, so pale that it probably was not intentional ; on the contrary, this would seem more likely to have been an attempt at colourless glass, which we know was more highly valued by the ancients, at least in the south of Europe, than any other. I could detect no colouring metallic oxide in the present specimen, except the merest trace of oxide of iron.

No. 5. An opaque, white bead, of a flattened form, from the same locality with the last. On examination it proved not to be glass at all, but pure crystalline white marble (carbonate of lime), which had been very neatly cut to the required shape, and the surface well polished. This material has not, I believe, been hitherto noticed among those employed for these primitive ornaments.

The results of the examination of these glasses agree very well with those of some of the specimens of KLAPROTH and Sir H. DAVY ; but further investigation of the Celtic articles (and indeed of those from the south of Europe) would be important in order to elucidate the history of this ancient manufacture, as it is only from the analysis of numerous examples, varying in date and locality, that we can hope to derive any valuable general information on the subject.

Another highly interesting branch of an inquiry as to the means of decoration possessed by the ancients is that concerning their

PIGMENTS,

and hence I have been most anxious to examine such remains of this kind as might be in existence in Ireland ; but have only succeeded in obtaining specimens (used in fresco painting) from a single locality, namely, Slane Abbey, in the county of Meath ; and these probably do not belong to an earlier date than 1512, as the Abbey, originally established in the seventh century, was re-founded in that year. These specimens were not contained in the Academy Museum, but were detached by Mr. F. W. BURTON, a member of the Academy, and presented for the purposes of this examination. There were

six varieties of colour examined, all of which had been laid on upon a uniform white ground of about the twentieth of an inch in thickness, or perhaps a little thicker, as part of the ground had no doubt been lost in removing the stucco from the walls. The coats of colour were a little thinner, but were not uniform, being thicker in some places than in others; they were all mixed with an oily substance used in very small quantity, which was soluble in alcohol and ether, reprecipitable from the former on the addition of water; want of sufficient material made it impossible to determine its nature more accurately. The ground or basis upon which the colours were laid consisted of carbonate of lime mixed with a little silica, or rather white siliceous clay, which, as well as the colours themselves, had been carefully and finely ground. The examination of the individual pigments gave the following results:—

No. 1 was a dull red, almost a brick colour, but somewhat brighter. Heated before the blowpipe on charcoal, it fused into a black shining bead, and in the reducing flame gave globules of a soft, white metal, which on examination proved to be lead. Digested in diluted nitric acid it partially dissolved with effervescence. The solution gave with hydro-sulphuric acid a black precipitate of sulphuret of lead, and with ammonia, after filtration and heating, a slight reddish-brown one of peroxide of iron, containing a trace of alumina. On fluxing the residue, insoluble in nitric acid with carbonate of soda, it was found to consist of highly ferruginous silica. Hence this colour appears to be an impure oxide of iron, probably iron ochre, mixed with carbonate of lead; or possibly may have been red lead, mixed with ground hæmatite, the former having altered in chemical composition in the lapse of time, by the action of air and moisture, &c.

No. 2. A pale yellow, verging on Naples yellow or yellowish white. Before the blowpipe it behaved nearly in the same manner as the red, but became much darker by the first application of the heat, before fusion. Treated in the same way as the last, it proved to be a light yellow ochre, mixed with a large proportion of ceruse, and containing a good deal of the oily matter with which the colours appear to have been mixed. Originally it may have been of an orange colour, and the lead, as in the last case, in the state of red lead.

No. 3. A light blue; the only one of the colours which had any pretensions to brilliancy. It invariably occurred over a coat of the red, No. 1; which probably was picked out or cut through in some places, so as to produce a

pattern of blue in relief on the red ground. It dissolved to a great extent with effervescence when heated in nitric acid, and the solution, on adding excess of ammonia, gave a pale blue solution of oxide of copper and a copious precipitate of oxide of lead. The insoluble residue was fluxed, and consisted of silica with alumina and oxide of copper, and probably an alkali. This colour, therefore, appears to have been partly a copper frit of the same kind with that found by Sir H. DAVY, in the blue pigments examined by him in Italy, but differing from these latter in that some of the copper existed in a state soluble in acids, I believe as carbonate. Before the blowpipe, this, like the other colours, yielded metallic lead when heated on charcoal, and empyreumatic products in a closed glass tube.

No. 4. White. This turned out to be slightly impure carbonate of lime, the same, in fact, as the basis of all the colours, though laid on in a separate layer. The fact of this being the white employed, and not white lead, which yet (or minium) was mixed with the other pigments, would seem to indicate either that the ceruse was prepared of so impure a character as not to be a good white, or that it was known to darken by long exposure, where traces of sulphureted hydrogen were present in the atmosphere, and therefore was rejected as not a permanent colour.

No. 5. A grayish black. It became white by the gentle application of the blowpipe flame, and dissolved in nitric acid with copious effervescence, leaving a slight carbonaceous residue of a black colour, perfectly dissipated, with the exception of a trace of silica, by heating to redness for an instant on platina foil. The nitric acid solution contained nothing but lime. This therefore was a mixture of carbon in some form, probably lamp-black, with carbonate of lime.

No. 6 was a dull brown, which proved to be an ochre, containing silica, alumina, lime, and a large quantity of oxide of iron analogous to Nos. 1 and 2, but of a different shade. It was mixed, like them, with carbonate of lead.

These results with respect to ancient Irish pigments agree, as far as they go, to a remarkable extent with those of Sir H. DAVY's interesting investigation* of the ancient Roman pigments above referred to. The materials used

* Philosophical Transactions, 1815.

are in each instance the same, or nearly so. This is not wonderful, however, as we find that most of the materials are of the commonest and most easily obtained substances for the purpose, requiring but little preparation, and are of a durable and stable character ; hence naturally selected by the early artist, and, when once in use, not likely to cease to be so from the knowledge of them dying out, as that of difficult and rare preparations might easily have done. Two points of difference are, however, to be found between the Roman pigments and these Irish ones, namely, the *use of an oily medium* for mixing the colours from Slane Abbey, whereas such was not apparently employed by the Romans in their fresco paintings ; and the occurrence in the former of large quantities of ceruse or white lead, which, although known and described by Pliny and Vitruvius as a common colour, was not found by Sir H. DAVY in any of the specimens examined by him. Both circumstances tend to prove the more modern character of the Irish pigments.

Such are the results of the examination of these antiquities so far obtained. It will be seen that some classes of objects in the Academy Museum have not been spoken of at all, and that this investigation is very far from exhausting the subject with respect even to the departments discussed. Conscious of my unfitness for the task, I have left the bearings of these results upon archæology almost untouched ; yet the analyses and experiments above described are not, perhaps, absolutely barren in results of interest, and at least put on record a number of facts concerning the materials employed at early periods in Ireland for various purposes of the arts, which may possibly in some degree assist the researches of archæologists. In the hope that such may be the case I have ventured to lay them before the Royal Irish Academy, to the liberality of whose Council I am indebted for the specimens principally experimented upon.